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Global land use impact assessment on biodiversity and ecosystem services in LCA

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Land use and land use change have severe effects on biodiversity and the capacity of ecosystems to deliver services, such as biomass production or water filtration. Whereas research on impacts of land use on biodiversity is a well-established field, research on ecosystem services motivated by Daily (1997) is less developed, but steadily catching up. The Millennium Ecosystem Assessment (2005) on ecosystem changes has begun to address this gap and has highlighted the importance of nature's services for human well-being. Meanwhile, operational assessment methods support decision-makers in planning and optimizing landscapes with respect to biodiversity and multiple ecosystem services (Chan et al. 2006; Daily et al. 2009; Groot et al. 2010; Maes et al. 2012). However, until now, those methodologies have mainly focused on regional systems with distinct spatial boundaries. However, the ecological assessment of land use in product systems requires a global approach.

The basic motivation for this special issue is to integrate land use impacts on biodiversity and ecosystem services into life cycle assessment (LCA), to allow a more comprehensive impact assessment of globally distributed product systems. The work builds on the key elements for land use impact assessment within LCA that was developed in the phase 1 of the UNEP-SETAC Life Cycle Initiative (Milà i Canals et al. 2007). The methodology presented here is the outcome of the project LULCIA within the phase 2 of the UNEP-SETAC Life Cycle Initiative. The main contributors to the project have been PES, University of Bayreuth, Germany (Thomas Koellner), SEAC, Unilever, UK (Llorenç Milà i Canals), European Commission, Joint Research Centre, Italy (Miguel Brandão and Danielle Maia de Souza), NSSI, ETH Zurich, Switzerland (Laura de Baan), IWOE, University of St. Gallen, Switzerland (Ruedi Müller-Wenk), CIRAIG, Canada (Manuele Margni and Rosie Saad), LBP-GaBi, University of Stuttgart, Germany (Ulrike Bos, Tabea Beck, Jan-Paul Lindner and Bastian Wittstock), and CLIOPE, Facultad Regional Mendoza, Universidad Tecnologica Nacional, Argentina (Barbara Civit). After a long process of consensus building on framing the methodology, we achieved an operational LCIA method to assess the use of land anywhere on the globe (Koellner et al. 2013b) and developed a set of characterization factors that allows linking spatially explicit land use elementary flows of occupation and transformation (Koellner et al. 2013a) to impacts on biodiversity (de Baan et al. 2013; Souza et al. 2013) and services provided by terrestrial ecosystems (Müller-Wenk and Brandão 2010; Beck et al. 2010; Brandão and Milà i Canals 2013; Saad et al. 2013). These characterization factors were tested in a food case study (Milà i Canals et al. 2013). With this special issue, certainly not all problems related to the assessment of land use impacts on biodiversity and ecosystem services on a global scale could be solved. We see the following five major outstanding questions relevant for future research to improve the assessment of biodiversity and ecosystem services in LCA:

How to combine generic impact assessment with site-specific assessments? Although uncertainties of the current models are large they allow for the identification of potential problem areas related to land use impacts in the *background system* of a product and minimize the risk of problem shifting. However, such a generic assessment on a global scale cannot replace on-site assessment of ecosystems. Therefore, site-specific characterization factors for the

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foreground system (that part of the product system of major concern) should be developed by the LCA practitioner.

What is the appropriate reference situation? In this special issue, we propose using the potential natural vegetation (PNV) as a reference. However, depending on goal and scope of the study, another reference might be more suitable (e.g., land use mix in year 2000). Using PNV results in high occupation impacts in European as well as in tropical countries. This reference gives similar weights to land use impacts currently occurring and land use impacts that happened long ago in the past. Using the land use mix in 2000 as a reference would in contrast result in higher occupation impacts in a tropical country with high natural forest cover compared to a European country with currently low natural vegetation cover. The past deforestation of Europe is in this case treaded as a sunk cost to the environment. It is therefore advisable to compare the potential natural vegetation vs. current land use mix in its effect for the results.

Which impact categories do we relate to land use? Even though land use has often been utilised as an impact indicator, it should be strictly regarded as an inventory flow. Its ecological impact should be assessed alongside those from chemical emissions, water use and climate change in order to capture the combined effect on the area of protection *ecosystem quality* represented by the two endpoints *ecosystem services* and *biodiversity*. The open research question is which midpoint categories should be formulated to support such an integrated impact assessment. From a modelling point of view, such an integrated impact assessment is certainly very challenging. Sophistication of models for ecosystem services is needed to improve the impact assessment in LCA. One way forward is to utilise existing global models on ecosystem services (e.g. the model EPIC, Environmental Policy Integrated Climate, van der Velde et al. 2009) and calculate characterisation factors with them.

Direct vs. indirect land use impacts? The need to consider indirect land use effects depends on the scope of an LCA study, e.g. when large-scale shifts in land demand are modelled (e.g. as caused by public policy on bio-energy), indirect land use effects (e.g. bio-energy production is displacing food production leading to deforestation of land elsewhere) are relevant. In order to account for direct and indirect land use change, existing data and models need to be reviewed and approaches suggested for different situations.

How to weight different ecosystem services and biodiversity? In the weighing, we should try to separate "natural science-based" from "value-based" approaches. Economic valuations for specific ecosystem services and biodiversity might be a way forward to weight them with respect to the benefit they create for the society. However, putting monetary values on nature can certainly not capture the intrinsic values that species and ecosystems have, and therefore, we also need to explore environmental valuation methods as well as social valuations based on revealed or stated preferences held by stakeholders. For biodiversity as well as ecosystem services, this is important because objective measures can be very different from public perception.

For the next phase of UNEP-SETAC Life Cycle Initiative, a number of open challenges remain, as shown above. We propose ecosystem services as an additional endpoint in LCA parallel to biodiversity not only for land use, but also water use, toxic emissions and climate change. To account simultaneously for their ecological impacts would require the integration of our work presented in this special issue with work done on other environmental interventions. Towards this end, collaboration with other initiatives, inside and outside of the LCA field, is needed. Outside the LCA community, the ecosystem services concept is getting increasing attention by regional and national policy-makers and researchers develop models for regional to global assessments from which we can certainly learn. Assessing land use impacts in LCA is now made possible with a comprehensive set of characterisation factors offering global coverage and addressing most relevant impact pathways from land use. The methods still need refinement and testing in multiple case studies. All LCA practitioners, particularly those assessing land-based products (agriculture, forestry, mining, etc.), are strongly encouraged to use these factors and report on their pros and cons.

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References

Beck T, Bos U, Wittstock B, Baitz M, Fischer M, Sedlbauer K (2010) LANCA—land use indicator value calculation in life cycle assessment. Fraunhofer, Stuttgart

Brandão M, Milà i Canals L (2013) Global characterisation factors to assess land use impacts on biotic production. Int J Life Cycle Assess. doi:10.1007/s11367-012-0381-3

Chan KMA, Shaw MR, Cameron DR, Underwood EC, Daily GC (2006) Conservation planning for ecosystem services. PLoS Biol 4:1–15

Daily GC (ed) (1997) Nature's services: societal dependence on natural ecosystems. Island, Washington

Daily GC, Polasky S, Goldstein J, Kareiva PM, Mooney HA, Pejchar L, Ricketts TH, Salzman J, Shallenberger R (2009) Ecosystem services in decision making: time to deliver. Front Ecol Environ 7:21–28

de Baan L, Alkemade R, Koellner T (2013) Land use impacts on biodiversity in LCA: a global approach. Int J Life Cycle Assess. doi:10.1007/s11367-012-0412-0

Groot RSD, Alkemade R, Braat L, Hein L, Willemen L (2010) Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecol Complex 7:260–272

Koellner T, de Baan L, Beck T, Brandão M, Civit B, Goedkoop M, Margni M, Milà i Canals L, Müller-Wenk R, Weidema B, Wittstock B (2013a) Principles for life cycle inventories of land use on a global scale. Int J Life Cycle Assess. doi:10.1007/s11367-012-0392-0

Koellner T, de Baan L, Beck T, Brandão M, Civit B, Margni M, Milà i Canals L, Saad R, Souza DM, Müller-Wenk R (2013b) UNEP-SETAC guideline on global land use impact assessment on biodiversity and ecosystem services in LCA. Int J Life Cycle Assess (this issue)

Maes J, Paracchini ML, Zulian G, Dunbar MB, Alkemade R (2012) Synergies and trade-offs between ecosystem service supply, biodiversity, and habitat conservation status in Europe. Biol Conserv 155:1–12

Milà I, Canals L, Bauer C, Depestele J, Dubreuil A, Freiermuth Knuchel R, Gaillard G, Michelsen O, Müller-Wenk R, Rydgren B (2007) Key elements in a framework for land use impact assessment within LCA. Int J Life Cycle Assess 12:5–15

Milà i Canals L, Rigarlsford G, Sim S (2013) Land use impact assessment of margarine. Int J Life Cycle Assess. doi:10.1007/s11367-012-0380-4

Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: synthesis. Island, Washington

Müller-Wenk R, Brandão M (2010) Climatic impact of land use in LCA—carbon transfers between vegetation/soil and air. Int J Life Cycle Assess 15:172–182

Saad R, Koellner T, Margni M (2013) Land use impacts on freshwater regulation, erosion regulation and water purification: a spatial approach for a global scale. Int J Life Cycle Assess (this issue)

Souza DM, Flynn D, Rosenbaum RK, de Melo Lisboa H, Koellner T (2013) Land use impacts on biodiversity: proposal of characterization factors based on functional diversity. Int J Life Cycle Assess (this issue)

van der Velde M, Bouraoui F, Aloe A (2009) Pan-European regional-scale modelling of water and N efficiencies of rapeseed cultivation for biodiesel production. Glob Change Biol 15:24–37